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Nakamura

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(54) **ELECTRIC VEHICLE**

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See application file for complete search history.

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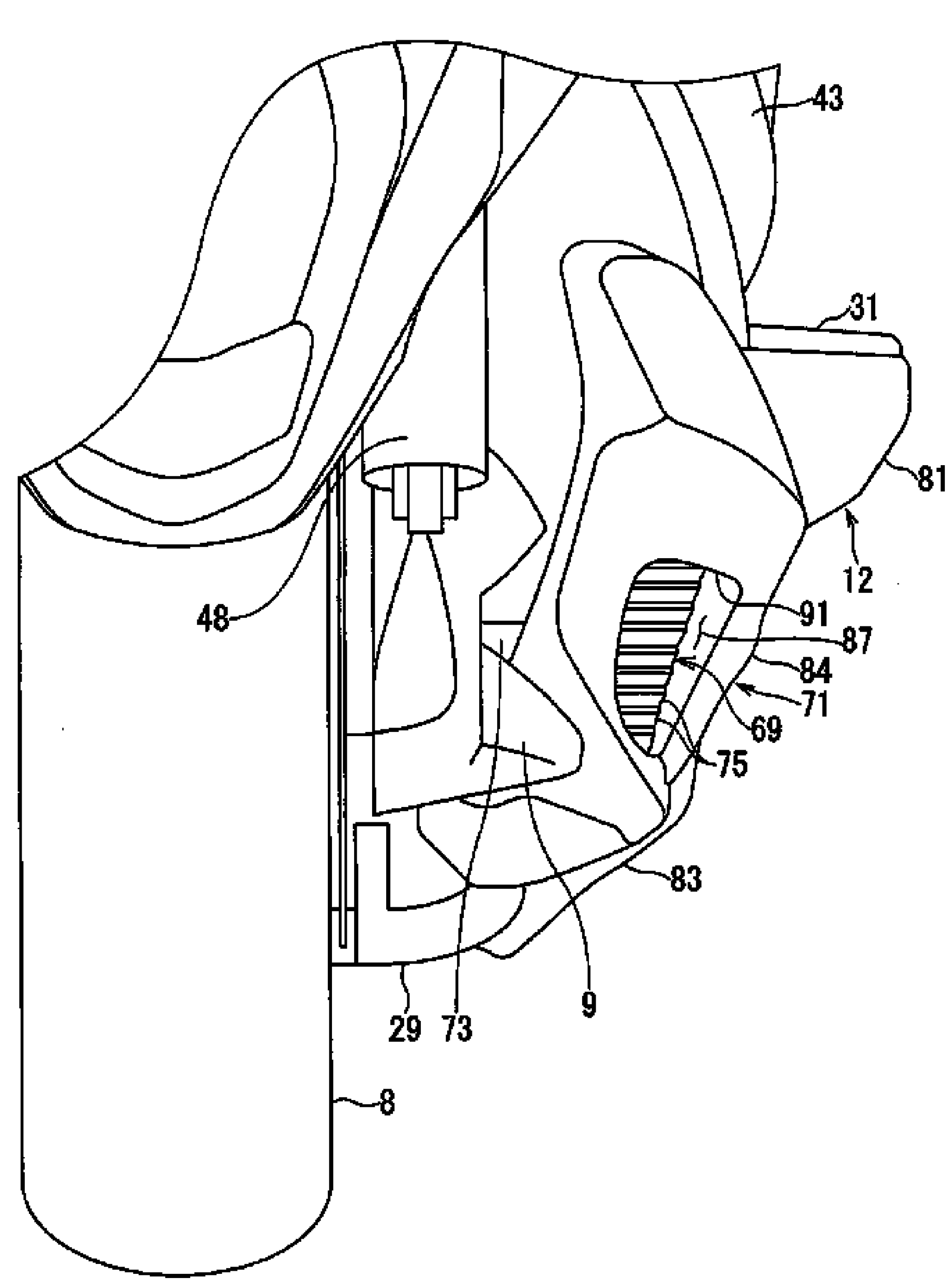
(57) **ABSTRACT**

An electric vehicle capable of efficiently and reliably cooling a power converter disposed inside an exterior. An electric vehicle includes a frame extending in a longitudinal direction, a power converter being long in the longitudinal direction along the frame, and an exterior extending in the longitudinal direction to cover the frame and the power converter, the exterior defining a cooling air path between the power converter to allow cooling air to flow through the cooling air path along the longitudinal direction. The power converter extends in the longitudinal direction in the cooling air path, and includes a plurality of heat radiation fins protruding toward an inner surface of the exterior, and the exterior includes an air induction port provided at a front end of the cooling air path to allow travelling wind to flow into the cooling air path.

8 Claims, 11 Drawing Sheets



(51) **Int. Cl.**

B60K 1/00 (2006.01)
B60K 1/04 (2006.01)
B60K 7/00 (2006.01)

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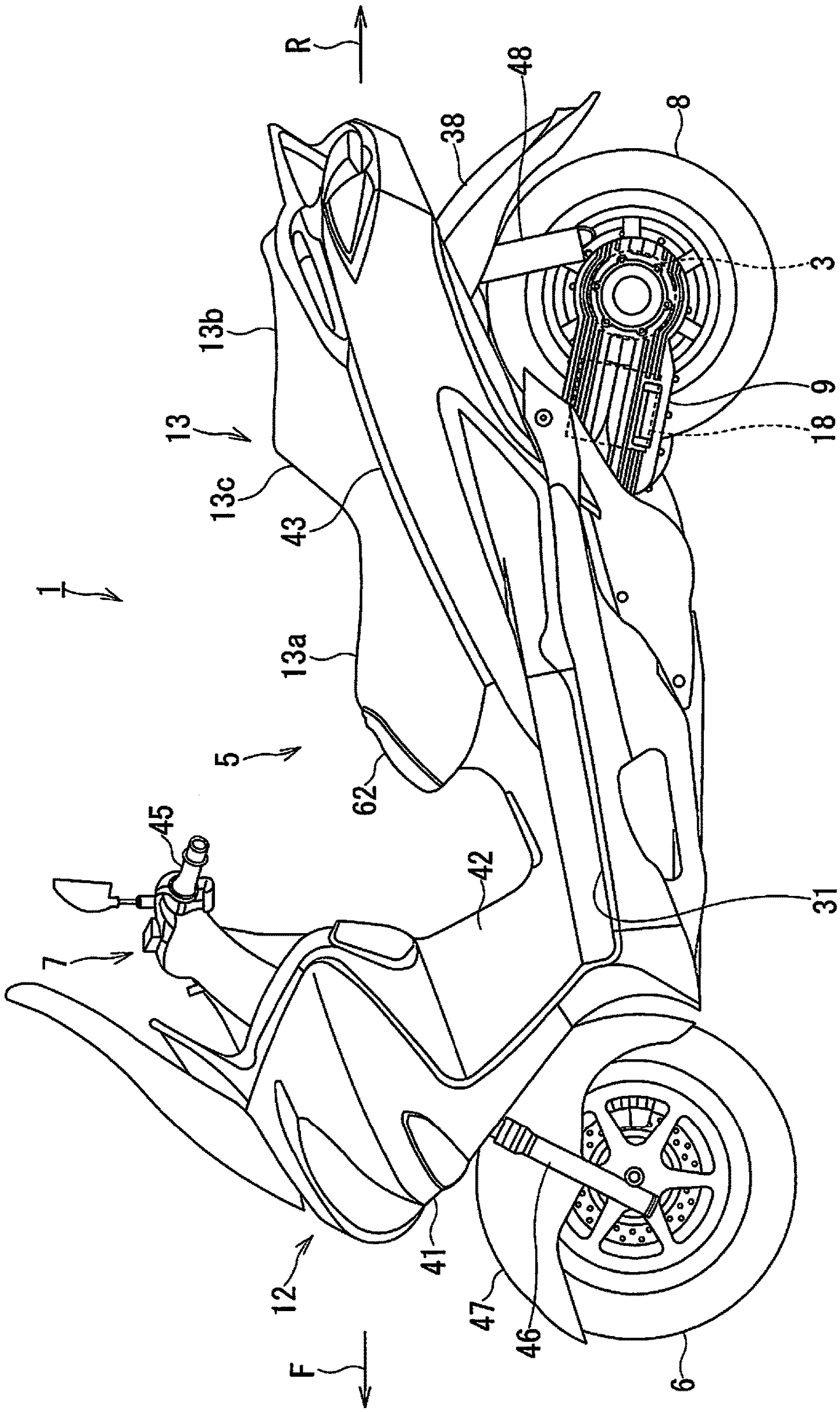
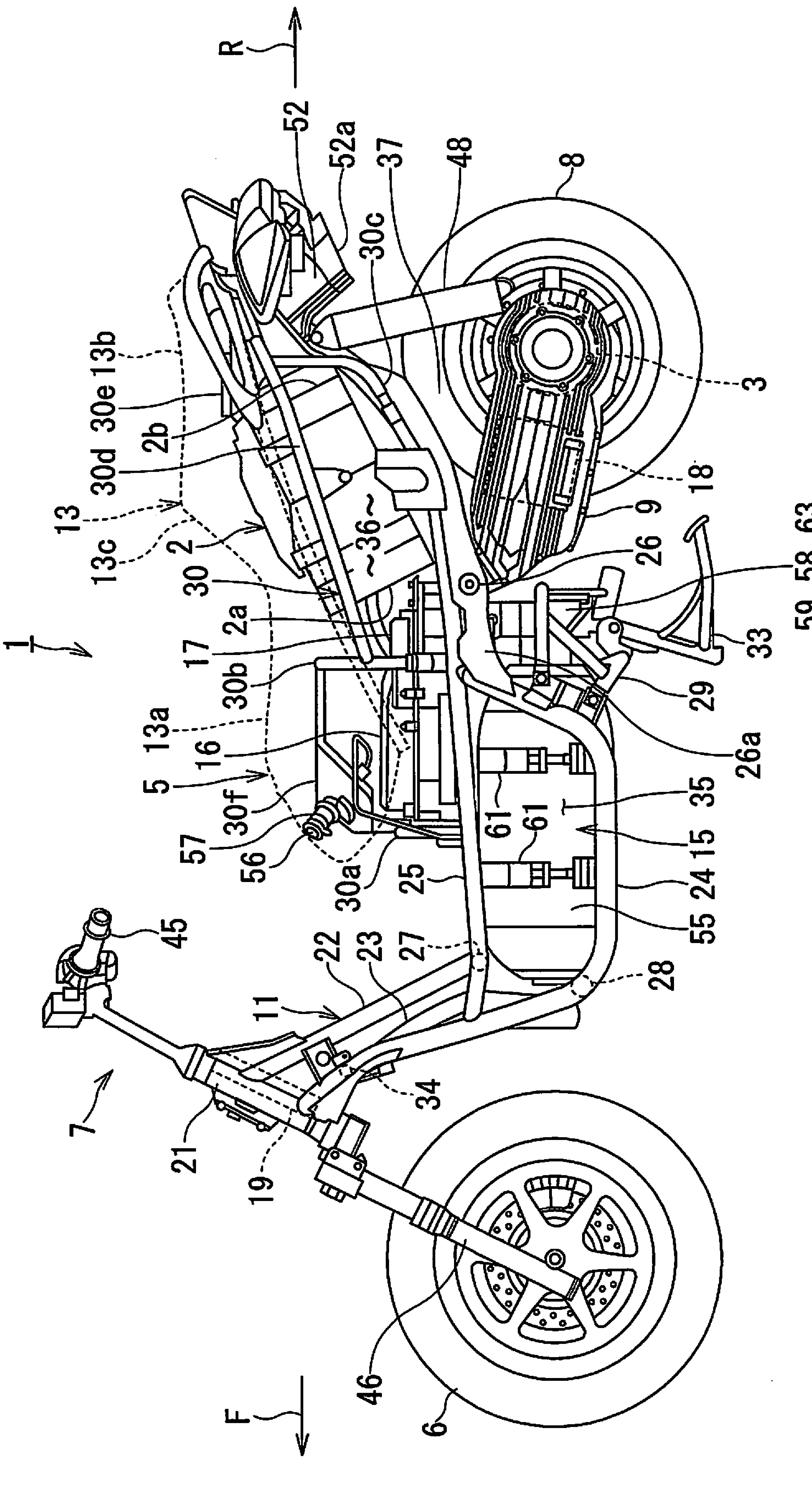


FIG. 1


R
52
52a
37
48
8
30c
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59, 58, 63
26
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26a
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28
34
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F
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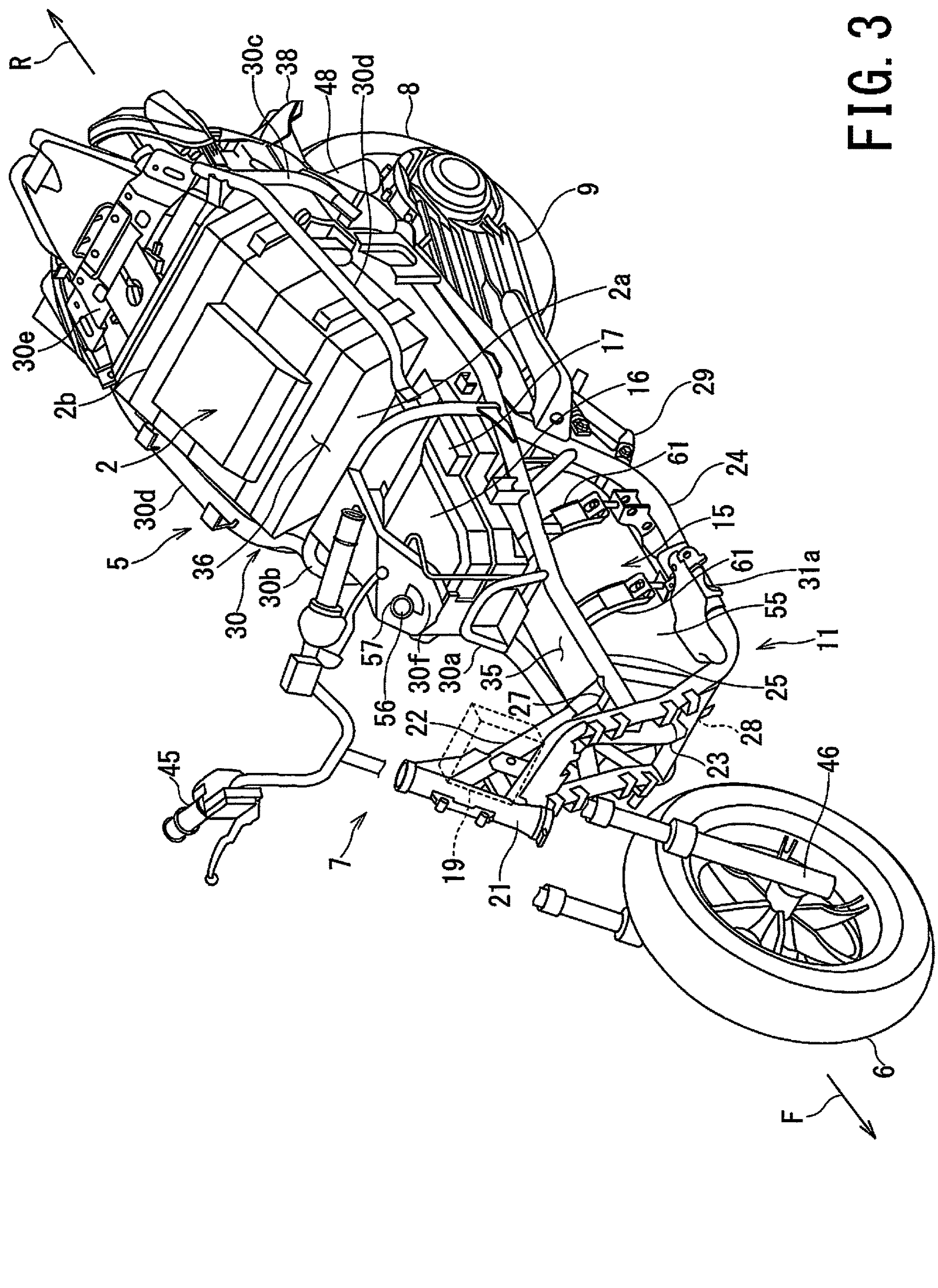
61
1

FIG. 2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30d
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57
56
30f
30a
35
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24
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F

FIG. 3

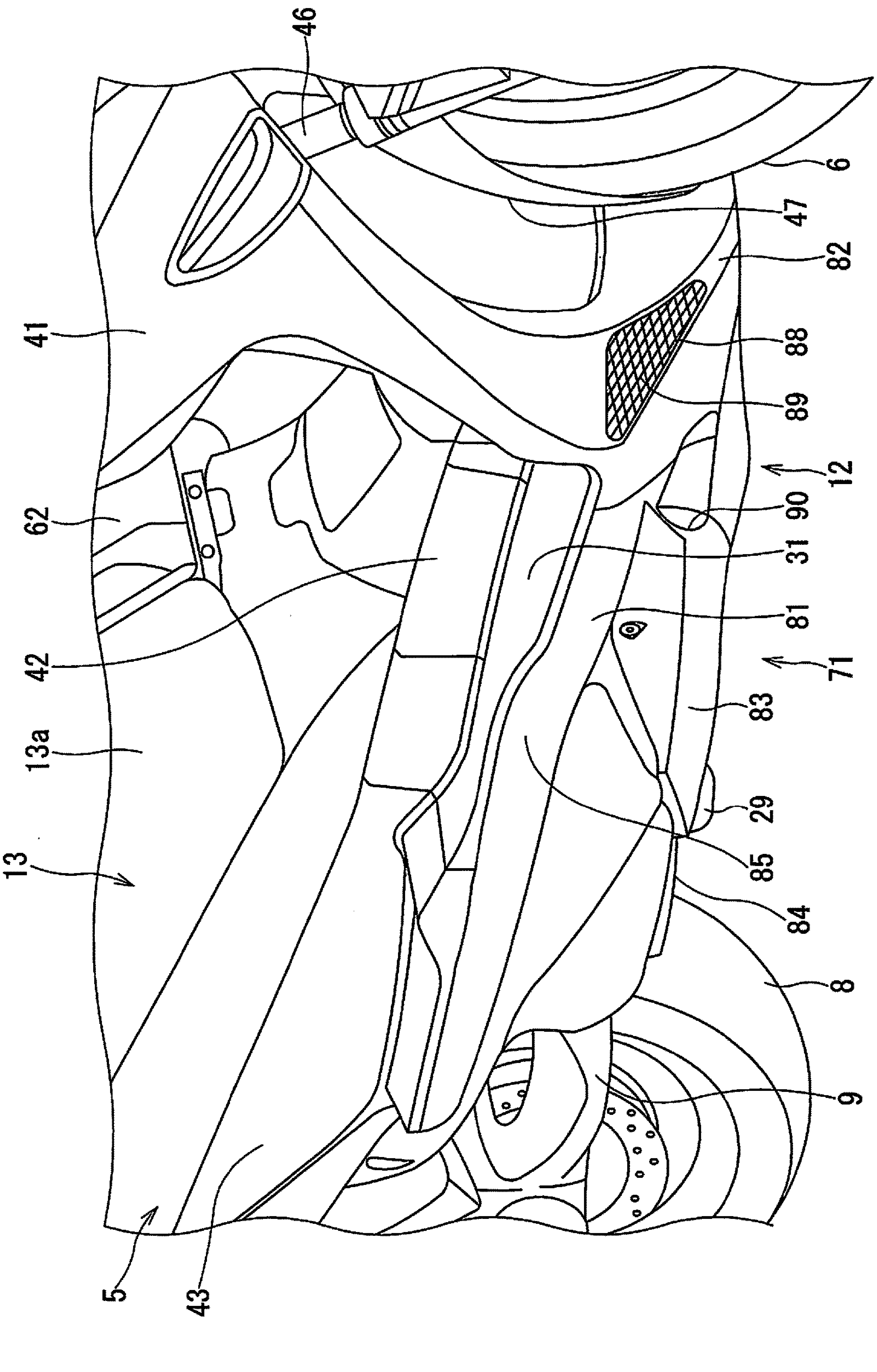

FIG. 4

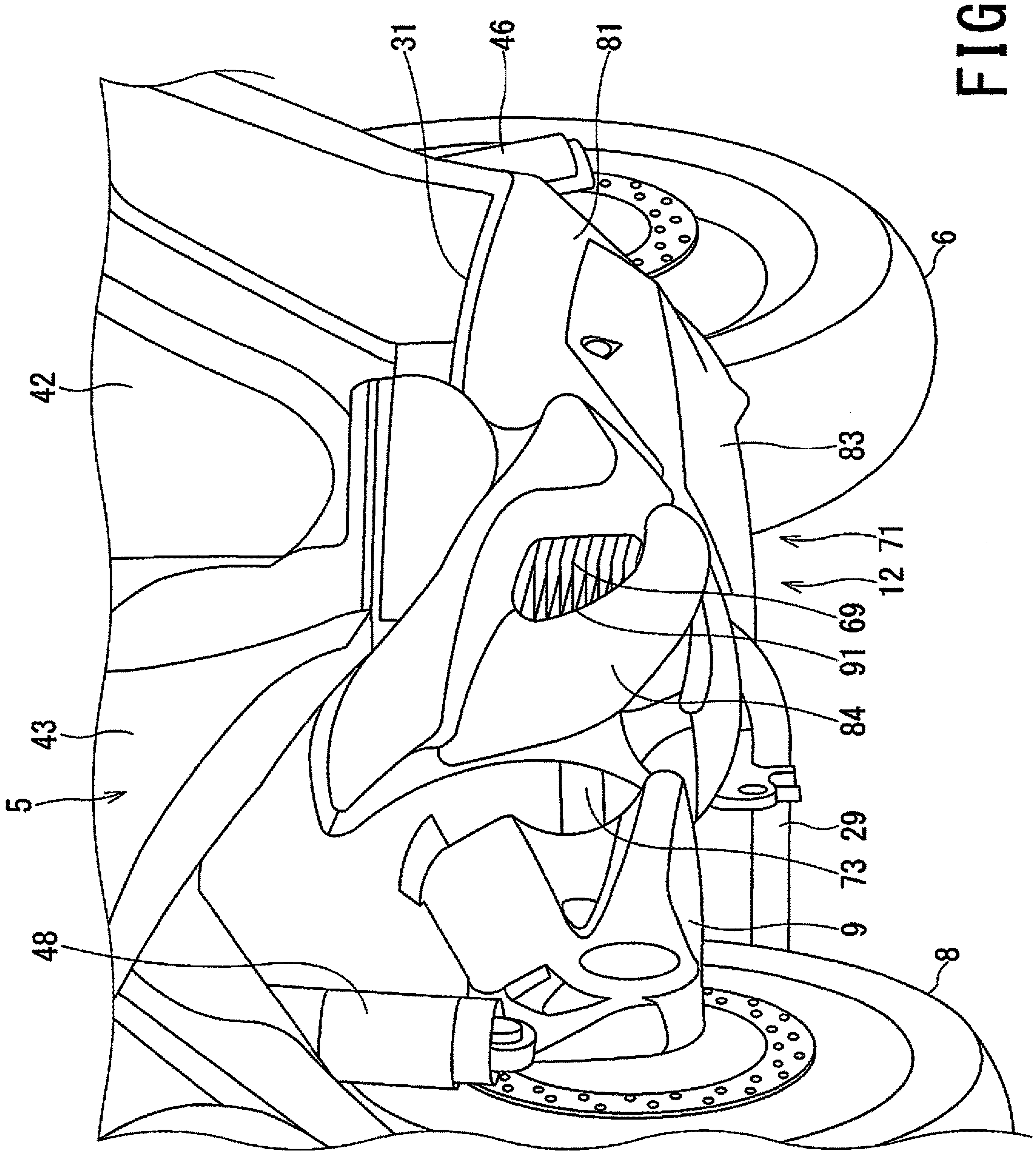

FIG. 5

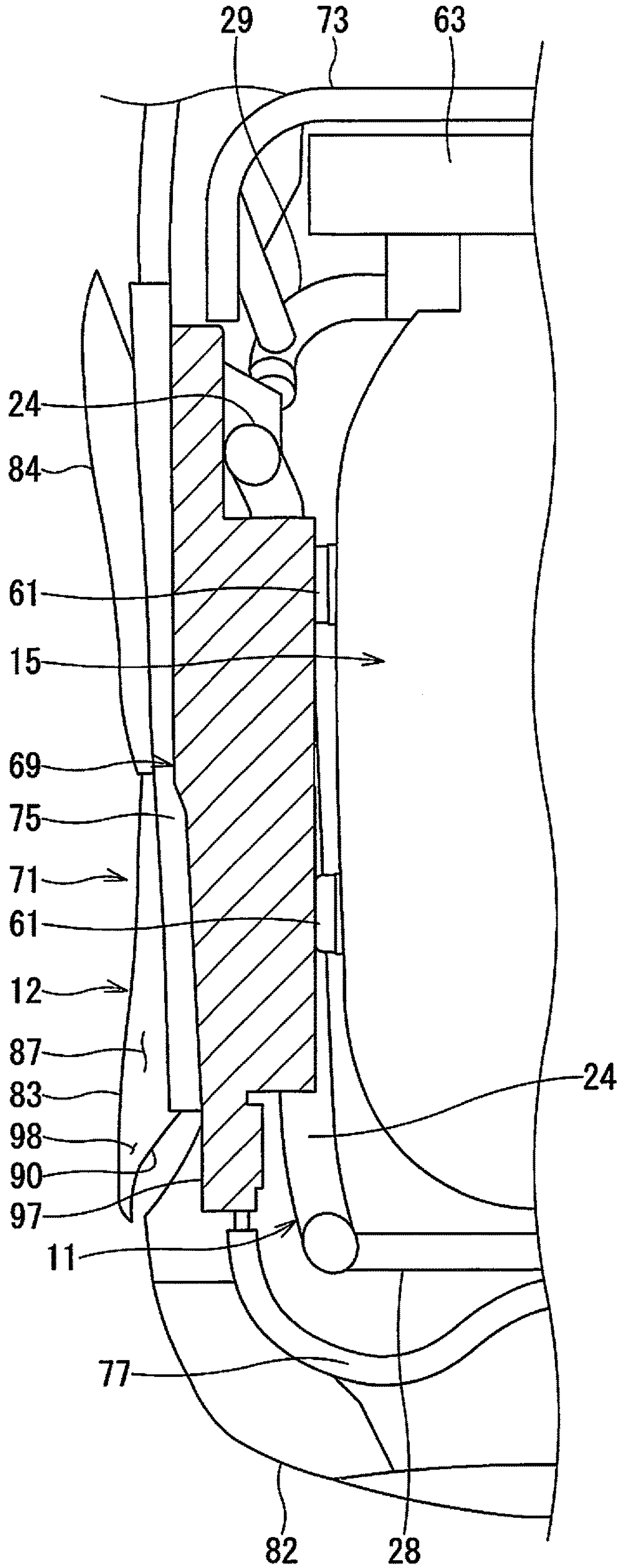

FIG. 6

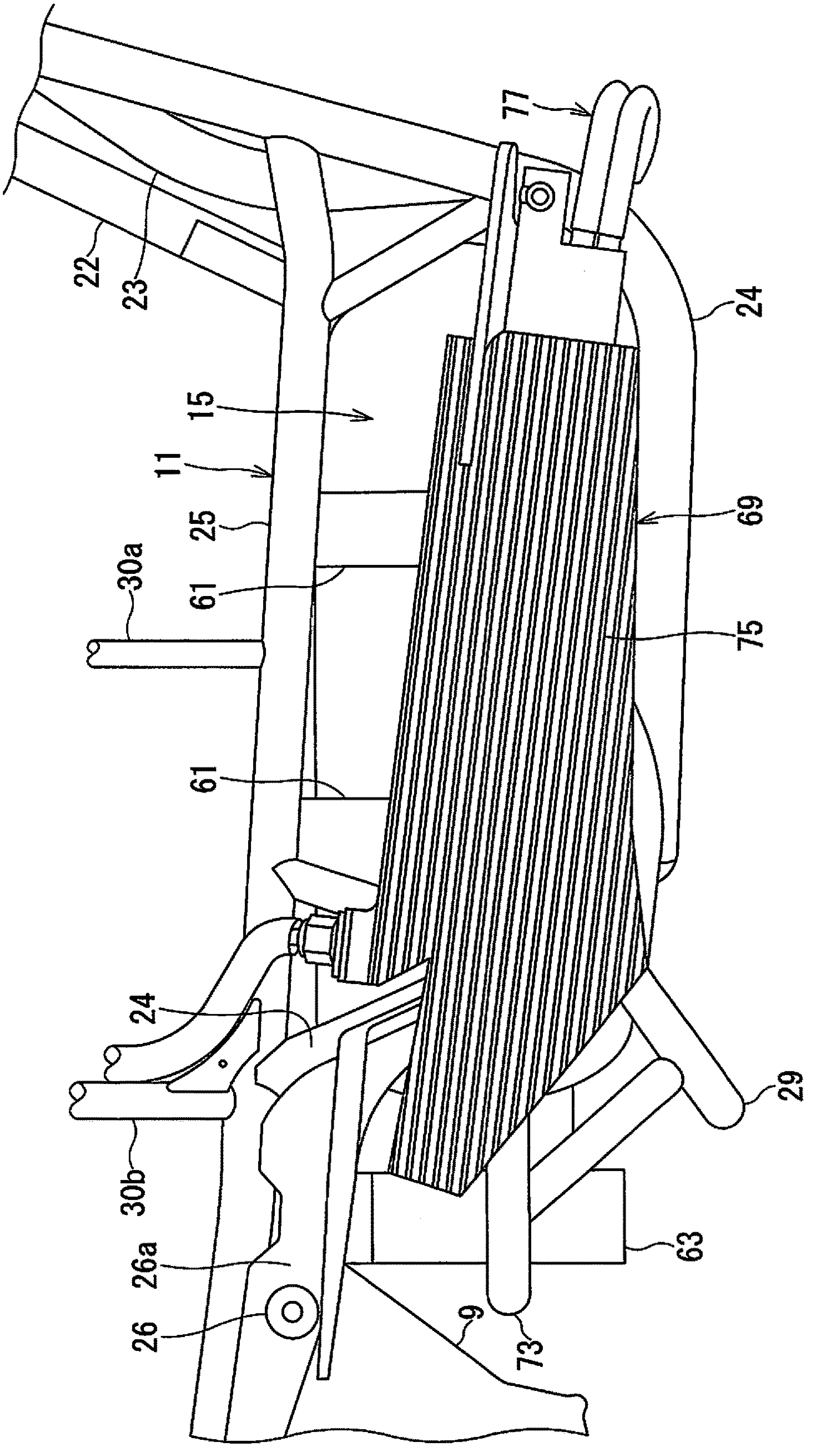

FIG. 7

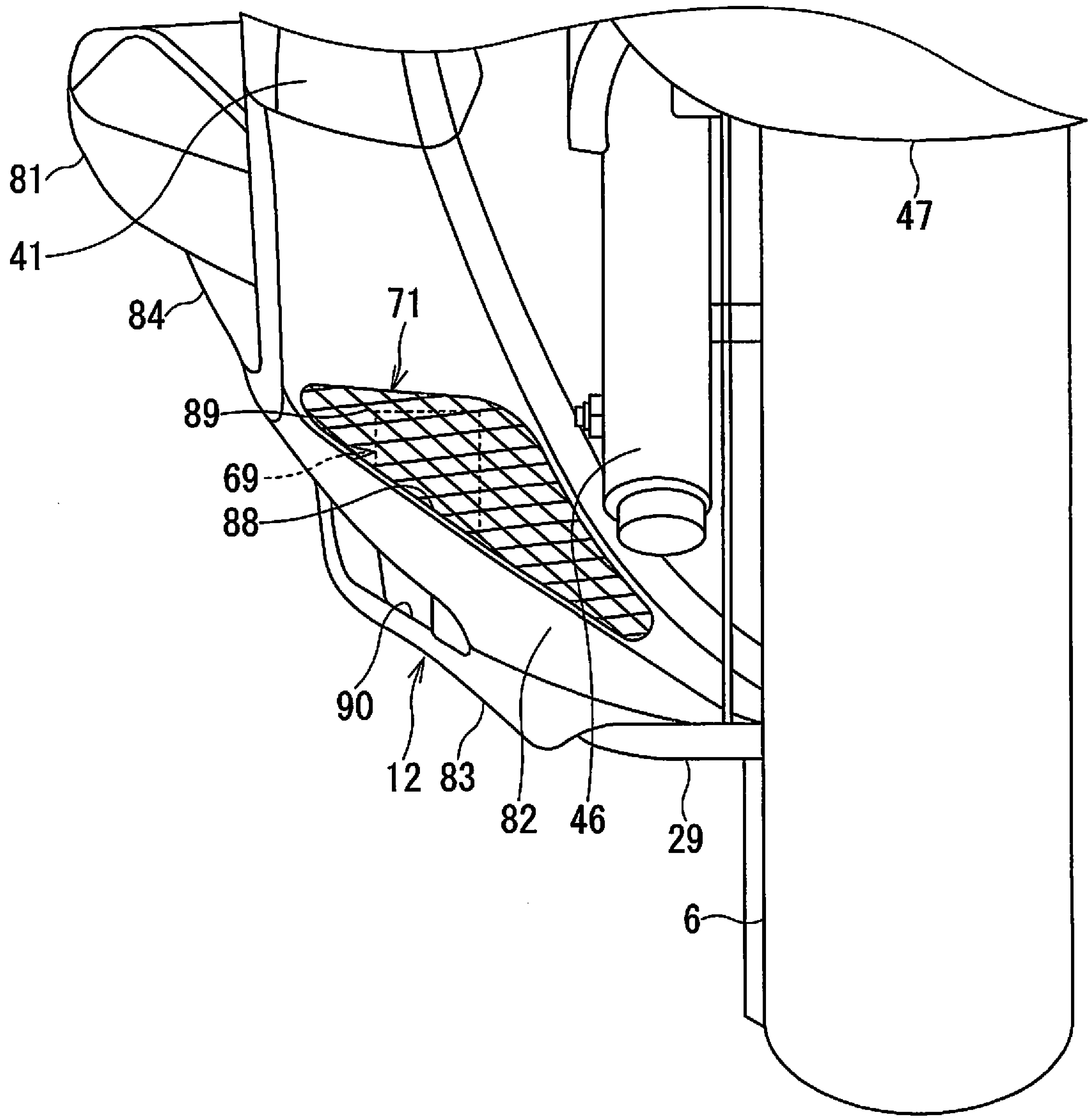

FIG. 8

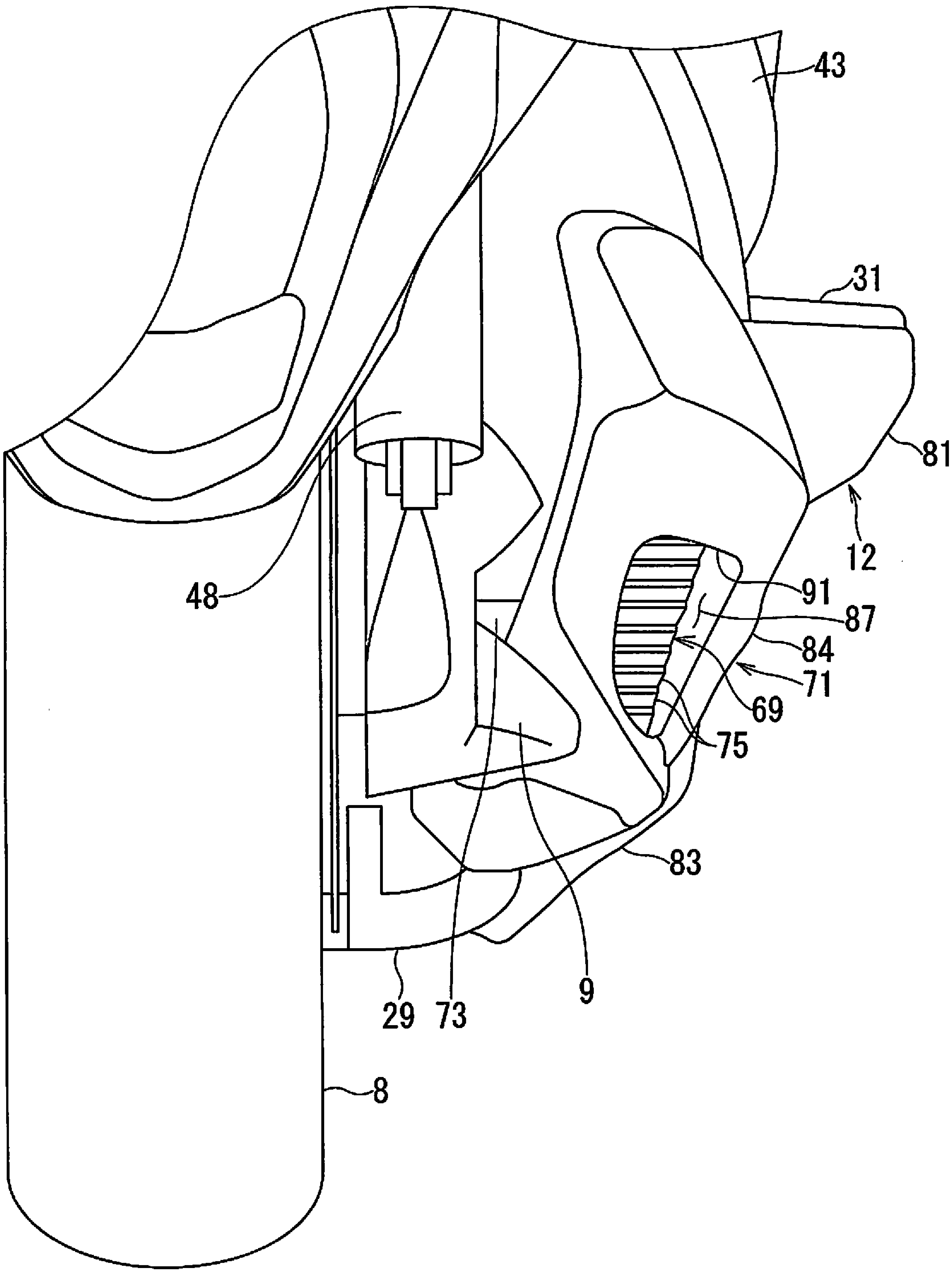

FIG. 9

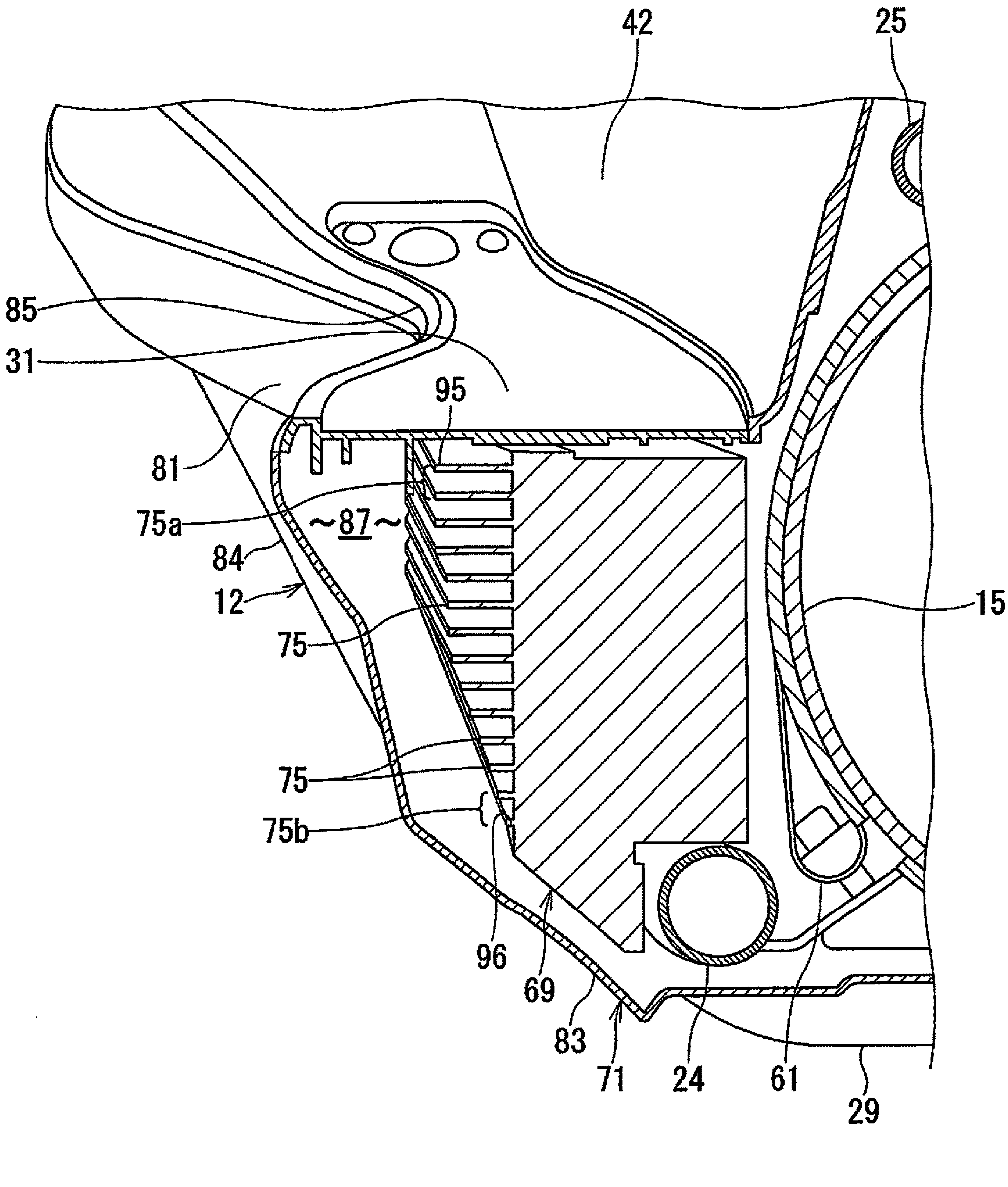

FIG. 10

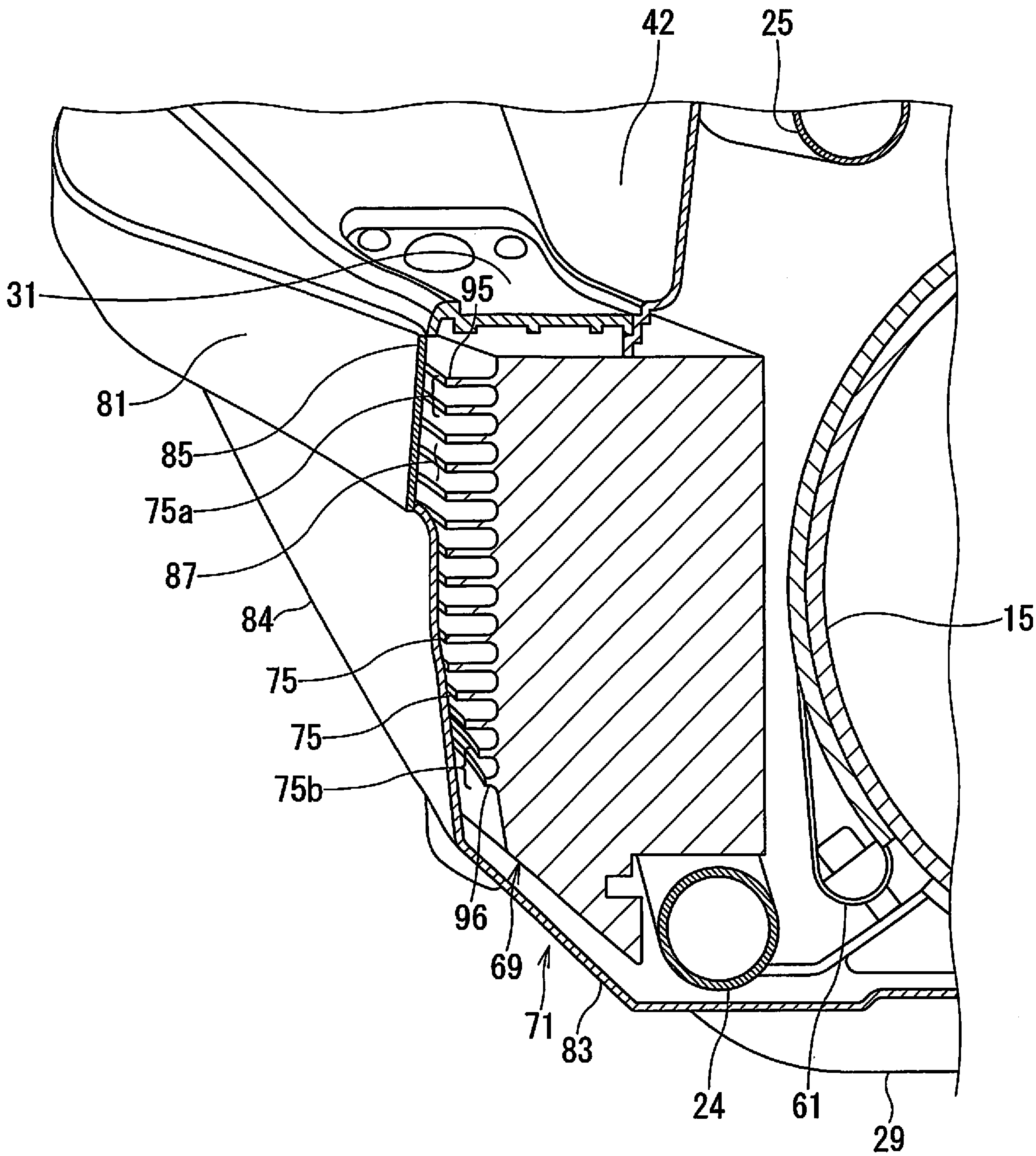

FIG. 11

ELECTRIC VEHICLE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of priority of Japanese Patent Application No. 2015-210401, filed on Oct. 27, 2015, the entire contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to an electric vehicle.

Description of the Related Art

There is known a fuel cell motorcycle in which a power converter, or specifically a DC-DC converter, is connected between a fuel cell and an electric motor, and output of the electric motor is transmitted to a rear wheel.

This conventional fuel cell motorcycle includes a DC-DC converter disposed on any one of right and left sides of a rear wheel (e.g. refer to Patent Document 1 (Japanese Patent Laid-Open No. 2002-187587)).

SUMMARY OF THE INVENTION

The conventional fuel cell motorcycle includes the DC-DC converter provided along with a frame inside an exterior with which the frame is covered, and the fuel cell, the DC-DC converter, and an electric motor controller are cooled by travelling wind passing through the inside of the exterior during travelling.

Unfortunately, the conventional fuel cell motorcycle only allows heat radiation fins provided in the DC-DC converter to be exposed to travelling wind passing through the inside of the exterior. Such an exterior structure of the DC-DC converter cannot allow a sufficient amount of air to flow between the heat radiation fins in which air resistance increases as compared with the periphery of the DC-DC converter, and contrarily allows air to detour in the periphery of the DC-DC converter so as to avoid the heat radiation fins, thereby deteriorating in cooling efficiency.

To solve the problems described above, it is an object of the present invention to provide an electric vehicle capable of efficiently and reliably cooling a power converter disposed inside an exterior.

To achieve above object, an aspect of the present invention provides an electric vehicle according to the present invention including a frame extending in a longitudinal direction, a power converter that is long in the longitudinal direction along the frame, an exterior that extends in the longitudinal direction to cover the frame and the power converter, and that defines a cooling air path for the power converter to allow cooling air to flow the cooling air path along the longitudinal direction. The power converter extends in the longitudinal direction in the cooling air path, and has a plurality of heat radiation fins protruding toward an inner surface of the exterior. The exterior includes an air induction port that is provided at a front end of the cooling air path to allow travelling wind to flow into the cooling air path.

This electric vehicle is capable of efficiently and reliably cooling a power converter disposed inside an exterior.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a left side view of an electric vehicle according to an embodiment of the present invention;

FIG. **2** is a left side view of the electric vehicle according to the embodiment of the present invention, with its exteriors being detached;

FIG. **3** is a perspective view of the electric vehicle according to the embodiment of the present invention, with its exteriors being detached;

FIG. **4** is a perspective view of an exterior structure of the electric vehicle according to the embodiment of the present invention;

FIG. **5** is a perspective view of the exterior structure of the electric vehicle according to the embodiment of the present invention;

FIG. **6** is a plan view of the exterior structure of the electric vehicle according to the embodiment of the present invention;

FIG. **7** is a right side view of the exterior structure of the electric vehicle according to the embodiment of the present invention;

FIG. **8** is a front view of the exterior structure of the electric vehicle according to the embodiment of the present invention;

FIG. **9** is a rear view of the exterior structure of the electric vehicle according to the embodiment of the present invention;

FIG. **10** is a sectional view of the exterior structure of the electric vehicle according to the embodiment of the present invention; and

FIG. **11** is a sectional view of the exterior structure of the electric vehicle according to the embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, an embodiment of an electric vehicle according to the present invention will be described with reference to FIGS. **1** to **11**.

FIG. **1** is a left side view of the electric vehicle according to the embodiment of the present invention.

FIG. **2** is a left side view of the electric vehicle according to the embodiment of the present invention in a state where exterior components, such as a cover and a seat, being detached.

FIG. **3** is a perspective view of the electric vehicle according to the embodiment of the present invention in a state where the exterior components, such as a cover and a seat, being detached.

Note that expressions of front-and-rear, up-and-down, and left-and-right in the present embodiment are based on reference to a rider onboard an electric vehicle **1**. In FIGS. **1** to **3**, a solid line arrow F represents forward of the electric vehicle **1**, and a solid line arrow R represents reward of the electric vehicle **1**.

As shown in FIGS. **1** to **3**, the electric vehicle **1** according to the present embodiment travels by being driven by an electric motor **3** powered by a fuel cell **2**. The electric vehicle **1** is a motorcycle of motor-scooter type, and also a fuel cell powered bicycle traveling by the power of the fuel cell **2**. The electric vehicle **1** may also be a tricycle. It may be a type of vehicle that travels by being driven by the electric motor **3** that is powered by a rechargeable battery (not shown) in place of the fuel cell **2**.

The electric vehicle **1** includes a vehicle body **5** extending forward and rearward, a front wheel **6** as a steered wheel, a steering mechanism **7** supporting the front wheel **6** in a steerable manner, a rear wheel **8** as a driving wheel, a swing arm **9** supporting the rear wheel **8** so as to be swingable in the up and down direction, and the electric motor **3** which generates driving power of the rear wheel **8**.

The vehicle body **5** includes a frame **11** extending forward and rearward of the vehicle, an exterior **12** covering the frame **11**, and a seat **13** disposed above a rear half part of the frame **11**.

Further, the vehicle body **5** includes a fuel cell **2**, a fuel tank **15** configured to store high pressure gas of hydrogen as a fuel to be used for power generation in the fuel cell **2**, a rechargeable battery **16** configured to supplement power of the fuel cell **2**, a power management apparatus **17** configured to adjust output voltage of the fuel cell **2** and control power distribution between the fuel cell **2** and the rechargeable battery **16**, an inverter **18** configured to convert DC power outputted by the power management apparatus **17** into three-phase AC power and outputs it to the electric motor **3** to operate the electric motor **3**, and a vehicle controller **19** configured to comprehensively control those mentioned before.

A power train of the electric vehicle **1** includes the fuel cell **2** and the rechargeable battery **16**, is a system which appropriately utilizes power of each power supply depending on travelling conditions of the vehicle, power generation conditions of the fuel cell **2**, and power storage conditions of the rechargeable battery **16**. The electric vehicle **1** generates regenerative power at the electric motor **3** during deceleration. The rechargeable battery **16** and the fuel cell **2**, which are power sources of the vehicle, are connected in parallel to the inverter **18** and supply power to the electric motor **3**. The rechargeable battery **16** stores regenerative power generated at the electric motor **3** when the electric vehicle **1** decelerates, and power generated by the fuel cell **2**.

The frame **11** is made up of a plurality of steel hollow pipes combined into a single body. The frame **11** includes a head pipe **21** disposed above the front end of the frame **11**, an upper down-frame **22** extending from a central part of the head pipe **21** in a rearwardly and downwardly inclined manner, a lower down-frame **23** disposed below the head pipe **21** and extending in a rearwardly and downwardly inclined manner, a pair of left and right lower frames **24**, a pair of left and right upper frames **25**, a pivot shaft **26**, an upper bridge frame **27**, a lower bridge frame **28**, a guard frame **29**, and a mounted-instrument protection frame **30**.

The head pipe **21** supports the steering mechanism **7** so as to be steerable, that is, to be swingable in the left and right direction of the electric vehicle **1**.

The pair of left and right lower frames **24** are disposed in the left and the right of the lower down-frame **23** and connected to a lower part of the head pipe **21**. The pair of left and right lower frames **24** each include a front-side inclined portion extending from a connected portion with the head pipe **21** substantially in parallel along the lower down-frame **23** and in a rearwardly and downwardly inclined manner, a front-side curved portion curved rearwardly at a lower end of the front-side inclined portion, and a straight portion extending substantially horizontally from a rear end of the front-side curved portion toward rearward of the vehicle body **5** in a linear manner until reaching a central portion of the vehicle body **5**, that is, a central portion in the front and rear direction of the electric vehicle **1**. The pair of left and right lower frames **24** each include a rear-side curved portion curved toward rearward and upward from a rear end part of the straight portion, a rear-side inclined portion extending from an upper end part of the rear-side curved portion in a rearwardly and upwardly inclined manner, and an upper and lower frame joining part connecting the rear-side inclined portion to the upper frame **25**. A spacing between the left and right lower frames **24** is wider than that between the left and right upper frames **25**.

A near-head-pipe bridge frame **34** is constructed between upper parts of the left and right lower frames **24**. The near-head-pipe bridge frame **34** extends in a linear manner substantially in the left and right direction of the electric vehicle **1**. Each of the left and right lower frames **24** includes a foot rest bracket **31***a*. The foot rest bracket **31***a* supports a foot board **31**, which is disposed on the outer side of the front-side curved portion, from below. A rider can lay its foot on the foot board **31**.

The lower frame **24** being disposed on the left side of the vehicle body **5** includes a side stand bracket (not shown). The side stand bracket (not shown) is provided with a side stand (not shown) configured to make the electric vehicle **1** stand by itself in a leftwardly inclined manner. The side stand swings between an erected position for making the electric vehicle **1** stand by itself, and a retracted position for making it stay along the vehicle body **5** so as not to impede travelling.

The pair of left and right upper frames **25** are connected to a central part in the up-and-down direction of the front-side inclined portion of the lower frame **24** in a front half part of the vehicle body **5**. The pair of left and right upper frames **25** each include, horizontal portions extending from a connected portion with the front-side inclined portion of the lower frame **24** toward rearward of the vehicle body **5** in a substantially horizontal manner, and rear end parts being rear ends of the horizontal portions of the pair of left and right upper frames **25**, the rear end parts being significantly inclined rearwardly and upwardly in the rear half part of the vehicle body **5** and above the rear wheel **8**, the rear end parts curved inwardly in the left and right direction of the vehicle body **5** to come close to each other to an extent of about thickness (width size) of the rear wheel **8**.

The pivot shaft **26** is constructed between the left and right upper frames **25** in the rear half part of the vehicle body **5**. The pivot shaft **26** is constructed between a pair of left and right brackets **26***a*. Each of the brackets **26***a* is located below the upper frame **25** and in the rear of a merging portion (upper and down frame joining part) between the upper frame **25** and the lower frame **24**. Each of the brackets **26***a* is connected to the horizontal portion of the upper frame **25**, and to the rear-side inclined portion of the lower frame **24**.

The upper bridge frame **27** is constructed between the front end parts of the left and right upper frames **25**. The upper bridge frame **27** extends substantially linearly in the left and right direction of the vehicle between the left and right upper frames **25** to interconnect the left and right upper frames **25**.

The lower bridge frame **28** is constructed between the front-side curved portions of the left and right lower frames **24**. The lower bridge frame **28** extends substantially linearly in the left and right direction of the vehicle between the left and right lower frames **24** to interconnect the left and right lower frames **24**.

The guard frame **29** is constructed between the rear-side curved portions of the left and right lower frames **24**. The guard frame **29** extends rearwardly and downwardly from a connected portion with the left and right lower frames **24**, and extends into a rearwardly declined U-shape so as to enlarge the internal space of the frame **11**. The guard frame **29** is provided with a center stand **33** configured to make the electric vehicle **1** stand by itself in an upright state. The center stand **33** swings between an erected position for making the electric vehicle **1** stand by itself, and a retracted position for making it stay along the vehicle body **5** so as not to impede travelling.

The upper down-frame **22** is constructed between the head pipe **21** and the upper bridge frame **27**.

The lower down-frame **23** includes an upper end part connected to a central part in the left and right direction of the electric vehicle **1** of a near-head-pipe bridge frame **34** constructed between the left and right lower frames **24**, and a lower end part connected to a central part in the left and right direction of the electric vehicle **1** of the lower bridge frame **28**.

The mounted-instrument protection frame **30** is provided above the rear half part of the upper frame **25**. The mounted-instrument protection frame **30** supports and secures the fuel cell **2** to the electric vehicle **1**. A part of the mounted-instrument protection frame **30** can be attached and detached to and from the upper frame **25**.

The seat **13** extends forward and rearward covering an upper section of the rear half part of the frame **11**. The seat **13** is of a tandem type and includes a front half part **13***a* on which the rider is to be seated, a rear half part **13***b* on which a passenger is to be seated, and an inclined part **13***c* between the front half part **13***a* and the rear half part **13***b*.

Here, a space surrounded by the left and right upper frames **25** and the left and right lower frames **24** is referred to as a center tunnel region **35**. A space surrounded by the rear half part of the upper frame **25**, exterior **12**, and the seat **13** as an instrument mounting region **36**. A space in the rear of the center tunnel region **35** and below the instrument mounting region **36** as a tire house region **37**.

The center tunnel region **35** accommodates the fuel tank **15**. In the electric vehicle **1** of a motor-scooter type according to the present embodiment, the center tunnel region **35** is disposed along the front and rear direction of the electric vehicle **1** and between left and right foot boards **31** on which the rider places its foot, and rises higher than the foot board **31** such that the foot resting region of the foot board **31** is divided into left and right sections. In other words, the foot board **31**, which serves as the foot resting region, is disposed in the left and right of the center tunnel region **35**, and the fuel tank **15** is disposed between the left and right foot boards **31**.

The instrument mounting region **36** accommodates the rechargeable battery **16**, the power management apparatus **17**, and the fuel cell **2** in this order from the front side of the vehicle body **5**. The mounted-instrument protection frame **30** protects the front end part, the central part, the rear end part, and a side part ranging from the central part to the rear end part of the instrument mounting region **36**.

The mounted-instrument protection frame **30** surrounds the instrument mounting region **36** and protects instruments to be mounted in the instrument mounting region **36**. The mounted-instrument protection frame **30** includes a front protection frame **30***a* disposed in the front end part of the instrument mounting region **36**, the front protection frame **30***a* being constructed between the left and right upper frames **25** in an upwardly convex arch shape, a center protection frame **30***b* disposed in a central part of the instrument mounting region **36** and in the rear of a merging spot between the upper frame **25** and the lower frame **24**, the center protection frame **30***b* being constructed between the left and right upper frames **25** in an upwardly convex arch shape, a pair of left and right rear protection frames **30***c* disposed at a rear end part of the instrument mounting region **36**, the pair of left and right rear protection frames **30***c* being connected to a portion where each of the left and right upper frames **25** is curved inwardly, the pair of left and right rear protection frames **30***c* extending rearward and obliquely upward from the curved portion, a pair of left and right side protection frames **30***d* extending rearward from each of the left and right of the center protection frame **30***b* to be connected to the upper end parts of the rear protection frames **30***c*, the pair of left and right side protection frames **30***d* reaching the rear end part of the vehicle body **5**, a bracket **30***e* constructed between rear end parts of the left and right side protection frames **30***d*.

The left and right upper frames **25** are bent at a spot where the lower ends of the front protection frame **30***a* are joined thereto, increase the spacing therebetween toward the rear of the electric vehicle **1**. The left and right upper frames **25** are bent at a spot where the lower ends of the center protection frame **30***b* are joined thereto, and extend to the rear of the electric vehicle **1**. Thus, the center protection frame **30***b* has a larger width and a larger height than those of the front protection frame **30***a*. The rear protection frame **30***c* and the pair of the left and right side protection frames **30***d* are integrated.

The rear protection frame **30***c* and the pair of left and right side protection frames **30***d* are detachably interconnected to the center protection frame **30***b* and the upper frames **25**, thereby supporting the fuel cell **2**.

A rear wheel **8** is disposed in the tire house region **37**.

Between the instrument mounting region **36** and the tire house region **37**, a rear fender **38** as a partition member for dividing respective regions is provided.

The exterior **12** includes, a front leg-shield cover **41** covering a front half part of the vehicle body **5**, a front frame cover **42** disposed above the center of the vehicle body **5** and covering an upper section of the upper frame **25** such as the center tunnel region **35**, and a frame cover **43** disposed in a rear half part of the vehicle body **5** and covering a lower portion of the seat **13**.

The frame cover **43** along with the seat **13** surrounds the instrument mounting region **36**. The instrument mounting region **36** is a closed space surrounded by the seat **13**, the frame cover **43**, and the rear fender **38**. The instrument mounting region **36** easily and securely controls flow of air to the fuel cell **2** by means of a vent hole (not shown) provided in an appropriate area of the frame cover **43** or the rear fender **38**, and also easily and securely controls flow of air as a cooling wind to an apparatus, which needs to be cooled. The instrument mounting region **36** allows air to enter from, for example, a joint of each cover (such as the front frame cover **42**, and a frame cover **43**).

The steering mechanism **7** is disposed in a front section of the vehicle body **5** and swings in the left and right direction centering on the head pipe **21** of the frame **11**, thereby enabling steering of the front wheel **6**. The steering mechanism **7** includes a handle **45** provided in a top part, and a pair of left and right front forks **46** interconnecting the handle **45** and the front wheel **6**, and the pair of left and right front forks **46** extending in the up and down direction slightly inclined rearwardly. The left and right front forks **46** have a telescopic structure that can be elastically expanded and contracted. An axle (not shown) for rotatably supporting the front wheel **6** is constructed between lower end parts of the left and right front forks **46**. The front fender **47** is disposed above the front wheel **6**. The front fender **47** is located between the left and right front forks **46**, and secured to the front fork **46**.

The front wheel **6** is a driven wheel that is rotatable about the axle constructed between the lower end parts of the left and right front forks **46**.

The swing arm **9** swings in the up and down direction about the pivot shaft **26** as a rotational center extending in the left and right direction of the vehicle body **5**. The swing arm **9** rotatably supports the rear wheel **8** between a pair of arms extending in the front and rear direction on left and right sides of the vehicle body **5**, respectively. A rear suspension **48** is constructed between the frame **11** and the swing arm **9**. The upper end part of the rear suspension **48** is swingably supported at the rear end part of the upper frame **25**. The lower end part of the rear suspension **48** is swingably attached to the rear end part of the swing arm **9**. The rear suspension **48** buffers the swinging of the swing arm **9**.

The swing arm **9** accommodates a electric motor **3** rotationally driving the rear wheel **8**, and an inverter **18** converting DC power supplied from the fuel cell **2** into AC power to supply it to the electric motor **3**.

The electric motor **3** rotationally drives the rear wheel **8** with power supplied from the fuel cell **2** or the rechargeable battery **16**, thereby causing the electric vehicle **1** to travel. The electric motor **3** is accommodated in a rear part of the swing arm **9** and coaxially disposed with the axle of the rear wheel **8**. The electric motor **3** is integrally assembled to the swing arm **9** to constitute a unit-swing-type swing arm.

The inverter **18** is accommodated in a front part of the swing arm **9**, and disposed between the pivot shaft **26** and the electric motor **3**. The inverter converts DC power outputted by the power management apparatus **17** into three-phase AC power, and adjusts the rotational speed of the electric motor **3** by altering the frequency of the AC power.

The rear wheel **8** is the driving wheel being supported by the axle (not shown) to which driving force is transferred from the electric motor **3**.

The fuel cell **2** generates power by causing reaction between a fuel and an oxidizing agent. The fuel cell **2** is an air-cooled fuel cell system generating power by using a high pressure gas, for example, hydrogen gas as the fuel, and oxygen in the air as the oxidizing agent, and is cooled by using air.

The fuel cell **2** is disposed on the rear half side of the instrument mounting region **36**. The fuel cell **2** is disposed below the seat **13** over a range from an inclined part between the front half part **13***a* and rear half part **13***b* to the rear half part **13***b*. That is, in the side view of the vehicle, the fuel cell **2** is disposed between the rear half part **13***b* of the seat **13**, on which the passenger is to be seated, and the rear wheel **8** and the swing arm **9**.

The fuel cell **2** has a cuboidal shape having a long side extending in the front and rear direction of the vehicle body **5**, and is disposed in the instrument mounting region **36** in a posture in which its front face, in which the intake port **2***a* is disposed, faces forward and obliquely downward, and its back face, in which the exhaust port **2***b* is disposed, faces rearward and obliquely upward. That is, the fuel cell **2** is secured to the frame **11** in a forward leaning posture in which its front side is located lower than its rear side. The upper part of the fuel cell **2** is secured to a mounted instrument protection frame **30** and the lower part of the fuel cell **2** is secured to the upper frame **25**.

The fuel cell **2** includes a plurality of flat modules interconnected from the front side toward the rear side. The fuel cell **2** includes a filter (not shown), an intake shutter (not shown), a fuel cell stack (not shown), a fan (not shown), and an exhaust shutter (not shown), which are interconnected by being superposed on each other in a laminated state in order from the front side. A fuel cell control unit (not shown) is provided on the top face of the fuel cell **2**.

The intake shutter includes an openable/closable intake port **2***a* of air, and configured to control the amount of air introduced to the fuel cell stack by opening/closing the intake port **2***a*. The intake shutter configured to constitute a circulation path for circulating air in the fuel cell **2** by closing the intake port **2***a*. The exhaust shutter includes an openable/closable exhaust port **2***b* of air and configured to constitute the circulation path for circulating air in the fuel cell **2** by closing the exhaust port **2***b*. In other words, the fuel cell **2** includes the openable/closable intake port **2***a* in the front face, and the openable/closable exhaust port **2***b* in the back face, and configured to cause air to be circulated in the fuel cell **2** by closing the intake port **2***a* and the exhaust port **2***b*.

The fuel cell stack causes electrochemical reaction between oxygen contained in the air drawn through the intake port and hydrogen supplied from the fuel tank **15** to generate power, and produces a wet excess gas after generation.

The fan generates intake negative pressure for drawing air in the instrument mounting region **36** from the intake port into the fuel cell **2**, while drawing out the excess gas from the fuel cell stack and discharges it from the exhaust port. The flow of air being caused by the fan is used for the power generation in the fuel cell stack, as well as for the cooling of the fuel cell **2**.

An exhaust duct **52** is provided in the rear of the fuel cell **2**. The fan of the fuel cell **2** draws out excess gas from the fuel cell stack and discharges it to the exhaust duct **52**. The front end part of the exhaust duct **52** is airtightly connected to a box, which is a frame body of the exhaust shutter, of the fuel cell **2**. The exhaust duct **52** includes an exhaust port **52***a* opened toward rearwardly downward, and rearwardly upward at the rear end of the vehicle body **5**. The exhaust duct **52** guides exhaust gas (excess gas) ejected from the fan of the fuel cell **2** to the exhaust port **52***a* and discharges it to the rear of the vehicle body **5**.

The exhaust port **52***a* is disposed higher than the exhaust face (back face), and preferably at the upper end part of the rear section of the exhaust duct **52**. In other words, the upper edge part of the exhaust port **52***a* is disposed at a position higher than the exhaust port of the fuel cell **2**. As a result of having the exhaust port **52***a* disposed to be higher than the exhaust face (back face) of the fuel cell **2**, the exhaust duct **52** guides a wet excess gas containing unreacted hydrogen gas to the exhaust port **52***a* and securely discharge it from the vehicle body **5**.

The fuel tank **15** is a high-pressure compressed hydrogen storage system. The fuel tank **15** includes a pressure vessel **55** made of carbon fiber reinforced plastic (CFRP), or being a composite vessel made from an aluminum liner, a fuel filling joint **57** having a fuel filling port **56**, a fuel filling main valve **58**, a fuel supply main valve **59** integrally including a shut-off valve (not shown) and a regulator (not shown), and a secondary pressure reducing valve (not shown).

The pressure vessel **55** is a composite vessel made from an aluminum liner which stores hydrogen gas as fuel of the fuel cell **2**. The fuel tank **15** stores, for example, hydrogen gas of about 70 megapascal (MPa.) The pressure vessel **55** includes a cylinder-shaped barrel part, and a dome-shaped mirror plate provided on front and rear end faces of the barrel part. The pressure vessel **55** is disposed in the center tunnel region **35** with the central axis of the cylindrical barrel being aligned along the front and rear direction of the vehicle body **5**. The pressure vessel **55** is surrounded by a pair of upper frames **25**, a pair of lower frames **24**, a lower bridge frame **28**, and a guard frame **29**, and is robustly protected against load due to turning over or collision of the electric vehicle **1**.

The pressure vessel **55** is supported in the center tunnel region **35** by a clamp band **61** constructed between an upper frame **25** disposed at one side of the vehicle body **5**, for example, the upper frame **25** disposed at the right side of the vehicle body **5**, and a lower frame **24** disposed at another side of the vehicle body, for example, the lower frame **24** disposed at the left side of the vehicle body **5**. The pressure vessel **55** is placed on a lower clamp band, for example, a lower half part of the clamp band **61** being constructed between the right side upper frame **25** and an left side lower frame **24**, and is clamped by the upper clamp band, for example, an upper half part of the clamp band **61** to be sandwiched. Note that the clamp band **61** may be constructed between the upper frame **25** disposed at the left side of the vehicle body **5** and the lower frame **24** disposed at the right side of the vehicle body **5**.

The fuel filling joint **57** is disposed outside of the center tunnel region **35**, more specifically, rearwardly upward of the center tunnel region **35**, and at the front end part of the instrument mounting region **36**. The fuel filling joint **57** is disposed to be higher than or just above the rechargeable battery **16**. The fuel filling joint **57** is secured to the joint bracket **30***f* being constructed between the upper parts of the front protection frame **30***a* and the center protection frame **30***b* of the mounted-instrument protection frame **30**. The fuel filling joint **57** extends toward upward, and slightly leftward of the vehicle body **5** such that a facility side joint can be inserted from the upper side and left side of the vehicle body at the time of fuel filling. The fuel filling joint **57** is covered and hidden by the fuel filling port lid **62** being disposed at the front end of the seat **13**. The fuel filling port lid **62** is supported to the seat **13** via a hinge mechanism (not shown), and opens/closes by being swung. The fuel filling joint **57** has a fuel filling port **56** as an inlet for introducing high pressure gas of hydrogen as a fuel into the fuel tank **15**.

The fuel filling port **56** is disposed at a top part of the fuel filling joint **57**. The fuel filling port **56** is oriented toward the upper left of the vehicle body **5**. In filling the fuel tank **15** with fuel, the upward of the fuel filling port **56** is opened to the atmosphere in a state in which the fuel filling port lid **62** is opened. Thus, in charging high pressure gas, for example, hydrogen gas as fuel, into the fuel tank **15**, even if the high pressure gas leaks, the leaked fuel diffuses toward the upward of the electric vehicle **1** without residing therein.

A fuel filling main valve **58** and a fuel supply main valve **59** are integrated and incorporated in a tank valve **63** provided on the top part of the rear-side mirror plate of the pressure vessel **55**. The tank valve **63** is disposed in a space surrounded by the guard frame **29**. The fuel supply main valve **59** includes a shut-off valve (not shown) and a primary pressure reducing valve (not shown). The fuel filling main valve **58** and the shut-off valve of the fuel supply main valve **59** are an on-off valve using an electromagnetic valve. The primary pressure reducing valve and the secondary pressure reducing valve of the fuel supply main valve **59** successively reduce and thereby adjust the pressure of the high pressure fuel gas from the pressure vessel **55**.

The rechargeable battery **16** is a box-shaped lithium ion battery. The rechargeable battery **16** is disposed in the front end part of the instrument mounting region **36** and between the rear half part of the pressure vessel **55**, that is, the rear half part of the cylindrical barrel and the rear-side mirror plate, and the front half part **13***a* of the seat **13**.

Note that, the electric vehicle **1** includes, besides the rechargeable battery **16**, a second rechargeable battery (not shown) supplying, for example, 12V-based power as a power supply for meters (not shown) and lights (not shown). The second rechargeable battery is disposed around the head pipe **21**, for example, beside the right side of the head pipe **21**.

In the electric vehicle **1**, even if hydrogen gas as fuel leaks from the fuel filling port **56**, the hydrogen gas, which is lighter than air, moves up, thus diffusing to the outside of the electric vehicle **1** without residing within the electric vehicle **1**. Even if hydrogen gas as fuel leaks from the fuel filling main valve **58** or the fuel supply main valve **59**, the hydrogen gas moves toward the tire house region **37**, thus diffusing to the outside of the electric vehicle **1** without residing within the electric vehicle **1**.

The power management apparatus **17** is disposed between the rechargeable battery **16** and the fuel cell **2** in the instrument mounting region **36**, and is secured to the frame **11**. Note that the power management apparatus **17** may be disposed along with the rechargeable battery **16** in a same waterproof case.

By disposing the rechargeable battery **16**, the power management apparatus **17**, and the fuel cell **2** in a manner as described above, it becomes possible to dispose apparatuses adjoining to each other in the electrical connection to be closer to each other as much as possible, thus shortening the wiring length between the apparatuses, and reducing the weight relating to the wiring.

The vehicle controller **19** is disposed around the head pipe **21** being a relatively high place in the electric vehicle **1**, for example, beside the left side of the head pipe **21** corresponding to the opposite side of the second rechargeable battery, which supplies 12V-based power.

Next, an exterior structure of the electric vehicle **1** will be described in detail.

FIGS. **4** and **5** each are a perspective view of the exterior structure of the electric vehicle according to the embodiment of the present invention.

FIG. **6** is a plan view of the exterior structure of the electric vehicle according to the embodiment of the present invention.

FIG. **7** is a right side view of the exterior structure of the electric vehicle according to the embodiment of the present invention.

FIG. **7** illustrates a state where the exterior **12** is detached.

As shown in FIGS. **4** to **7**, an exterior structure **71** of the electric vehicle **1** according to the present embodiment includes the frame **11** extending in the longitudinal direction, a power converter **69** being long in the longitudinal direction along the frame **11**, the exterior **12** extending in the longitudinal direction to cover the frame **11** and the power converter **69**.

The power converter **69** is a DC-DC converter, for example. The power converter **69** has an input connected to the fuel cell **2** and the rechargeable battery **16**. The power converter **69** has an output connected to electric components such as meters (not illustrated) and lamps (not illustrated), and the second rechargeable battery. The power converter **69** converts direct-current power supplied from the fuel cell **2** and the rechargeable battery **16** into direct-current power of high voltage (e.g. 48 volt system) to be supplied to the electric motor **3** or direct-current power of 12 volt system to be supplied to the electric components other than the electric motor **3** to output the direct-current power.

The power converter **69** is disposed on any one of sides of the fuel tank **15**, for example, on a right side thereof. The power converter **69** has a length similar to that of the pressure vessel **55** of the fuel tank **15**, and extends in the longitudinal direction of the vehicle body **5** with its front and rear ends being substantially aligned with respective front and rear ends of the pressure vessel **55**. The front end of the power converter **69** is disposed behind the lower bridge frame **28** of the frame **11**. The rear end of the power converter **69** is disposed ahead a rear end of a valve protection frame **73**. The valve protection frame **73** is provided between inclined portions on a rear side of the right and left lower frames **24** to surround the fuel filling main valve **58** and the fuel supply main valve **59** (tank valve **63**) of the fuel tank **15**. The front end of the power converter **69** is fixed to the front-side inclined portion of the lower frames **24** with fasteners, for example, bolts (not illustrated). The rear end of the power converter **69** is fixed to the rear-side inclined portion of the lower frames **24** with fasteners, for example, bolts (not illustrated). The power converter **69** allows its front and rear ends to be fixed to the lower frames **24** to transmit its heat the lower frames **24**, thereby enabling heat dissipation, as well as to couple the front-side inclined portion and the rear-side inclined portion of the lower frame **24** to each other for reinforcement.

The power converter **69** includes a case in the shape of an elongated rectangular parallelepiped. The power converter **69** is disposed at a position above the lowermost portion of lower frame **24**. The power converter **69** has a left side face entering a space between the right upper frame **25** and the right lower frame **24** in the frame **11**, that is, the center tunnel region **35**. The left side face of the power converter **69** faces the pressure vessel **55**. The power converter **69** has a right side face facing an inner surface of the exterior **12**. The power converter **69** has a top face facing the right upper frame **25**. The power converter **69** has a bottom face facing the right lower frame **24**.

The right side face of the power converter **69**, that is, the face facing the exterior **12** includes a plurality of heat radiation fins **75**. The heat radiation fins **75** arrange vertically and extend in the longitudinal direction. The heat radiation fins **75** also extend backward along the foot board **31** of the exterior **12** at a slightly upward angle.

An electric power line **77** connected to the power converter **69**, that is, the electric power line **77** connecting the power converter **69** and the rechargeable battery **16** to each other is wired from the front end of the power converter **69** while detouring in front of the lower bridge frame **28** at the right side to the power converter **69**. An electric power line (not illustrated) connecting the power converter **69** and the fuel cell **2** to each other is attached to the rear end of the power converter **69**. The electric power line connecting the power converter **69** and the fuel cell **2** to each other is wired upward.

The exterior **12** includes the foot board **31**, a foot board lower cover **81** provided below the foot board **31**, a lower leg shield cover **82** with which a front face of the power converter **69** is covered, an undercover **83** connected to a lower end of the lower leg shield cover **82** to cover the power converter **69** together with a bottom portion of the frame **11**, and a rear lower fender cover **84** provided behind the undercover **83** to cover the power converter **69**.

The foot board **31** is connected to a lower end of each of the front frame cover **42** and the frame cover **43**, and has appropriate height and width allowing a rider and a fellow passenger to place their feet thereon.

The foot board lower cover **81** extends back and forth along an outer edge portion of the foot board **31**.

The lower leg shield cover **82** is connected to a lower end of the front leg shield cover **41** to cover a lower end of a front face of the vehicle body **5**. The lower leg shield cover **82** extends in a U-shape, as viewed from the front of the vehicle body **5**, to cover the lower frame **24** and the lower bridge frame **28** of the frame **11**.

The undercover **83** cover the fuel tank **15**, the right and left lower frames **24**, and the power converter **69** from below.

The rear lower fender cover **84** is provided below the frame cover **43** to constitute a right and left pair of rear lower fender covers **84**, and is disposed at a front end of the tire housing region **37** to cover a front end of the swing arm **9** supported by the pivot shaft **26** from the left and right sides to protect the front end of the swing arm **9**.

The exterior **12** is provided with a recessed portion **85** below the seat **13**, in particular substantially immediately below a front end of the seat **13**. The recessed portion **85** is provided in a part of the exterior **12**, for example, in the foot board **31** and the foot board lower cover **81**, and recessed toward a central side of the vehicle body **5**. The recessed portion **85** improves foot-grounding capability when a rider stops the vehicle or rides it.

The power converter **69** may be disposed on a left side of the fuel tank **15**. In this case, a right and left relationship among the frame **11**, the exterior **12**, and the power converter **69** is reversed.

FIG. **8** is a front view of the cooling structure of the power converter of the electric vehicle according to the embodiment of the present invention.

FIG. **9** is a rear view of the cooling structure of the power converter of the electric vehicle according to the embodiment of the present invention.

FIGS. **10** and **11** each are a sectional view of the cooling structure of the power converter of the electric vehicle according to the embodiment of the present invention.

FIG. **11** is a sectional view taken along the recessed portion **85**, and FIG. **10** is a sectional view taken along a general portion other than the recessed portion **85**.

As shown in FIGS. **8** to **11**, the exterior **12** of the exterior structure **71** according to the present embodiment extends in the longitudinal direction of the electric vehicle **1** to cover the frame **11** and the power converter **69**, and defines a cooling air path **87** for the power converter **69** to allow cooling air to flow through the cooling air path **87**. The cooling air path **87** extends along the longitudinal direction.

The cooling air path **87** is a space defined by the inner surface of the exterior **12**, that is, by an inner surface of each of the lower leg shield cover **82**, the undercover **83**, and an inner surface of the rear lower fender cover **84**, and a right side face of the power converter **69**. The cooling air path **87** extends in the longitudinal direction of the vehicle body **5** in the shape of a duct. The cooling air path **87** is defined by the exterior **12** expanding toward the outside of the vehicle body **5** with respect to the right side face of the planar power converter **69**, which is not limited. The cooling air path **87** may be defined by a combination of the power converter **69** having a right side face recessed toward a central side of the vehicle body **5** or a fuel tank **15** side, and a flat exterior **12**.

The exterior **12** includes an air induction port **88** provided at a front end of the cooling air path **87** to allow travelling wind to flow into the cooling air path **87**. The air induction port **88** is provided in the lower leg shield cover **82**, and is disposed in front of the power converter **69**. The air induction port **88** is disposed at a side of the front wheel **6** as viewed from the front of the electric vehicle **1**, and is opened toward the front of the electric vehicle **1**. The air induction port **88** is a triangular opening, as viewed from the front of the vehicle, extending toward a central side of the electric vehicle **1** so as to avoid the front fork **46**. The air induction port **88** includes a mesh filter **89**. The mesh filter **89** prevents a foreign matter such as a leaf from entering the cooling air path **87**. Behind the air induction port **88**, the front end of the power converter **69** extends toward the air induction port **88** and is disposed close to the air induction port **88**. The front end of the power converter **69** guides travelling wind flowing through the air induction port **88** to the cooling air path **87**, which is a space between the exterior **12** and the power converter **69**. The electric power line **77** is connected to the front end of the power converter **69**.

A right side face in a front end portion of the power converter **69** includes no heat radiation fin **75**, and serves as an air induction plate **97** guiding travelling wind into the cooling air path **87**. A cooling air guiding space **98** larger than the cooling air path **87** is disposed on a right side of the front end portion of the power converter **69**, that is, between the exterior **12** and the power converter **69**. The exterior **12** positioned outside the cooling air guiding space **98** is provided with a second air induction port **90** facing toward the front of the electric vehicle **1**. The second air induction port **90** is provided outside and below the air induction port **88** as viewed from the front of the electric vehicle **1**, and is positioned behind the air induction port **88**. The second air induction port **90** receives travelling wind flowing rearward from the periphery of the air induction port **88** to allow the travelling wind to be efficiently fed to the cooling air guiding space. The travelling wind captured through the second air induction port **90** is guided to the right side face in the front end portion of the power converter **69** together with travelling wind captured through the air induction port **88** to be efficiently fed into the cooling air path **87**, thereby cooling the power converter **69**. Even the second air induction port **90** is provided in the exterior **12** in front of the heat radiation fins **75** in the longitudinal direction of the electric vehicle **1**, it can be provided opposite to the heat radiation fins **75** to allow the travelling wind to be directly fed into the cooling air path **87**. The second air induction port **90** enables cooling performance to be improved by allowing powerful travelling wind to be directly fed into the cooling air path **87** to increase an air flow of cooling air flowing through the cooling air path **87**.

The exterior **12** includes an air exhaust port **91** provided at a rear end of the cooling air path **87** and facing the rear of the electric vehicle **1** to allow air to flow out from the cooling air path **87**. The air exhaust port **91** is provided in the rear lower fender cover **84**. The air exhaust port **91** is disposed behind the power converter **69**. The air exhaust port **91** is disposed at a side of the rear wheel **8** as viewed from the rear of the electric vehicle **1**, and is opened toward the back or rear of the electric vehicle **1** to allow air in the cooling air path **87** to be discharged by using a flow of air passing through the side of the electric vehicle **1**, that is, air flowing through the outside of the exterior **12**, as the electric vehicle **1** travels. The air exhaust port **91** avoids the swing arm **9** as viewed from the rear of the electric vehicle **1**. The heat radiation fins **75** are disposed in the air exhaust port **91** as viewed from the rear of the electric vehicle **1**.

The power converter **69** extends in the longitudinal direction in the cooling air path **87**. The power converter **69** includes the heat radiation fins **75** protruding toward the inner surface of the exterior **12**. The heat radiation fins **75** may be molded integrally with the case of the power converter **69**, or may be formed by thermally connecting a separated component to the case.

Some of the heat radiation fins **75**, which are heat radiation fins **75*a***, are closer to the inner surface of the exterior **12** than heat radiation fins **75*b*** at other portions. The heat radiation fins **75*a*** include a heat radiation fin **95** disposed at an uppermost portion, and a heat radiation fin **96** disposed at a lowermost portion.

That is, such the heat radiation fins **75*a*** are closer to the inner surface of the exterior **12** than the heat radiation fins **75*b*** at other portions, and the heat radiation fins **75*b*** at the other portions are farther from the inner surface of the exterior **12** than the heat radiation fins **75*a*** and have a larger gap. This gap between the heat radiation fins **75*b*** at the other portions and the exterior **12** is a part of the cooling air path **87** to serve as a duct guiding air to the heat radiation fins **75**. The heat radiation fins **75*a*** are closer to the inner surface of the exterior **12** than the heat radiation fins **75*b*** at other portions, and preferably are close to the extent of not being brought into contact with the inner surface to prevent travelling wind from leaking to the outside of the cooling air path **87** through the gap between the exterior **12** and the heat radiation fins **75**. An aspect of allowing the heat radiation fins **75*a*** at same portions and the inner surface of the exterior **12** to close to each other may be achieved by allowing the heat radiation fins **75*a*** to protrude more than the heat radiation fins **75*b*** at those portions, or by allowing the heat radiation fins **75** to uniformly protrude while the exterior **12** is expanded to allow only the heat radiation fins **75*a*** at same portions to be close to the exterior **12**, and an aspect of a combination of both aspects above is also available.

The foot board **31** of the exterior **12** is disposed closely to a top face of the power converter **69**. This reduces the gap between the exterior **12** and the power converter **69** to further prevent travelling wind from leaking.

The recessed portion **85** of the exterior **12** partially reduces a cross-sectional area of the cooling air path **87**. The protruding length of each of the heat radiation fins **75** is reduced along the recessed portion **85**. The recessed portion **85** allows the exterior **12** to be close to a leading end of each of the heat radiation fins **75** to partially reduce a cross-sectional area of the cooling air path, thereby increasing air velocity at the recessed portion to accelerate heat exchange at the heat radiation fins **75**, and thus cooling performance of the power converter **69** is improved. The recessed portion **85** may extend to a side closer to the power converter **69** than a virtual line connecting leading ends of the heat radiation fins **75** at the front and rear of the recessed portion **85**. In such manner, the heat radiation fins **75** allow air flowing through the cooling air path **87** to be urged to flow into a region where the protruding length of the heat radiation fins **75** are reduced, thereby improving the cooling performance. That is, the recessed portion **85** of the exterior **12** simultaneously improves foot-grounding capability of a rider in a case where the electric vehicle **1** is stopped, and the cooling performance of the power converter **69**. A circuit generating large heat in the power converter **69** is disposed near the recessed portion **85**, the circuit also can be efficiently cooled.

The electric vehicle **1** according to the present embodiment includes the plurality of heat radiation fins **75** protruding toward the inner surface of the exterior **12**, in the cooling air path **87**, and the air induction port **88** being provided in the exterior **12** to guide travelling wind into the cooling air path **87**, and thus the power converter **69** is efficiently cooled by guiding the travelling wind to the heat radiation fins **75** and allowing travelling wind to smoothly flow along the heat radiation fins **75**.

Further, the electric vehicle **1** according to the present embodiment enables the exterior **12** and the power converter

69 to define the cooling air path **87** in the shape of a duct, and thus no extra component is needed to cool the power converter **69**, and cooling efficiency of the power converter **69** is improved while the number of components being reduced.

Further, the electric vehicle **1** according to the present embodiment includes the air induction port **88** being disposed at a side of the front wheel **6** as viewed from the front of the vehicle, the air induction port **88** being faced the front of the electric vehicle **1**, and thus the cooling efficiency of the power converter **69** is improved by allowing the air induction port **88** to efficiently guide travelling wind, flowing through the periphery of the front wheel **6**, into the air induction port **88** without being blocked by the front wheel **6**.

Further, the electric vehicle **1** according to the present embodiment includes the air exhaust port **91** provided at the rear end of the cooling air path **87** to face the rear of the electric vehicle **1**, and thus the cooling efficiency of the power converter **69** is further improved by allowing air after cooling the power converter **69** to be smoothly discharged through the cooling air path **87** by using back pressure of the electric vehicle **1**.

Further, the electric vehicle **1** according to the present embodiment includes the recessed portion **85** partially reducing a cross-sectional area of the cooling air path **87**, and thus flow velocity is increased at a portion in the cooling air path **87** to increase cooling efficiency at the portion, whereby a circuit with a large heating value in the power converter **69**, for example, is intensively cooled, and also foot-grounding capability of the electric vehicle **1** is improved.

Thus, the exterior structure **71** of the electric vehicle **1** according to the present invention is capable of efficiently and reliably cooling a power converter **69** disposed inside the exterior **12**.

What is claimed is:

1. An electric vehicle comprising:

a frame extending in a longitudinal direction of the electric vehicle;

a power converter being long in the longitudinal direction of the electric vehicle along the frame; and

an exterior extending in the longitudinal direction of the electric vehicle to cover the frame and the power converter, the exterior defining a cooling air path for the power converter to allow cooling air to flow through the cooling air path,

wherein the power converter includes a plurality of heat radiation fins extending in the longitudinal direction of the electric vehicle in the cooling air path, the heat radiation fins protruding toward an inner surface of the exterior, and

wherein the exterior includes an air induction port provided at a front end of the cooling air path to allow travelling wind to flow into the cooling air path.

2. The electric vehicle according to claim **1**, wherein the air induction port is disposed at a side of a front wheel as viewed from a front of the electric vehicle, and faces forward of the electric vehicle.

3. The electric vehicle according to claim **1**, wherein the exterior includes an air exhaust port provided at a rear end of the cooling air path and facing rearward of the electric vehicle to allow air to flow out from the cooling air path.

4. The electric vehicle according to claim **2**, wherein the exterior includes an air exhaust port provided at a rear end of the cooling air path and facing rearward of the electric vehicle to allow air to flow out from the cooling air path.

5. The electric vehicle according to claim **1**, wherein the exterior includes a recessed portion partially reducing a cross-sectional area of the cooling air path.

6. The electric vehicle according to claim **2**, wherein the exterior includes a recessed portion partially reducing a cross-sectional area of the cooling air path.

7. The electric vehicle according to claim **3**, wherein the exterior includes a recessed portion partially reducing a cross-sectional area of the cooling air path.

8. The electric vehicle according to claim **4**, wherein the exterior includes a recessed portion partially reducing a cross-sectional area of the cooling air path.

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